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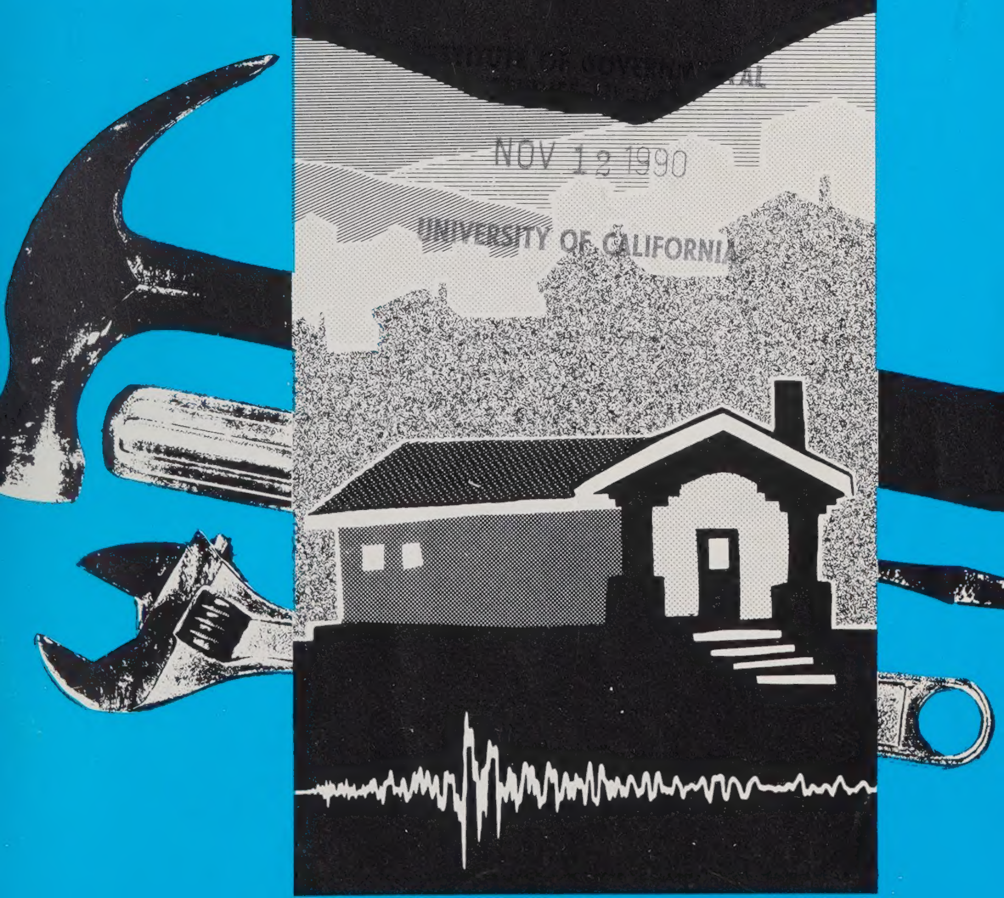
strengthening wood frame houses for earthquake safety



In recent earthquakes, wood frame houses have been damaged in ways that could have been prevented. Some relatively simple strengthening measures can greatly reduce the risk of injuries and property loss in an earthquake. This booklet has been published in order to encourage homeowners to consider upgrading their houses for earthquake safety. The booklet describes earthquake hazards common to wood frame structures, typical ways to minimize those hazards, and the approximate costs of making older wood frame houses safer in earthquakes.

It is not possible to identify every potential problem that may be encountered in the process of upgrading a home. The information herein is not a substitute for structural design or evaluation by a licensed civil or structural engineer or architect, nor for assessment of site characteristics by a licensed engineering geologist or geotechnical engineer.

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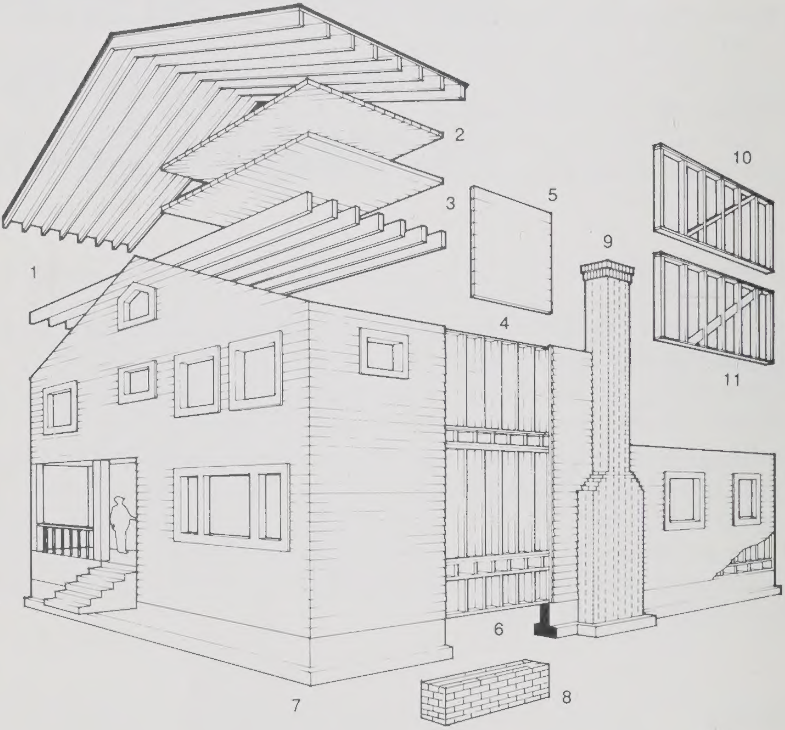
Strengthening Wood Frame Houses for Earthquake Safety

In even moderate earthquakes, your house can shake violently from side to side, toppling the chimney, cracking walls, and even shifting off its foundation. During the shaking, the contents of the house can be thrown about and damaged or destroyed. To protect your family and secure your investment here in earthquake country, you may need to strengthen your wood frame house. This booklet explains common weaknesses found in wood frame houses and describes how to make such houses stronger. The remodeling necessary to make a house safer in earthquakes is not especially complicated, but you will need some basic information in order to plan the process carefully. The organization of this booklet is indicated briefly below.

Contents



DESCRIPTION OF TYPICAL BUILDINGS

Roof/floor span system:
1. wood joist and rafter
2. diagonal sheathing
3. straight sheathing

Foundation/connections:
6. unbraced cripple wall
7. concrete foundation
8. brick foundation

Wall systems:
4. stud wall
5. horizontal siding

Bracing and details:
9. unbraced brick chimney
10. diagonal blocking
11. let-in brace

Modified graphics from Lagorio, Friedman, & Wong, *Issues for Seismic Strengthening of Existing Buildings: A Practical Guide for Architects*, 1986

Figure 1: Typical wood frame house construction.

I. Introduction

Wood Frame Construction

Almost all houses in California are wood frame structures. Wood frame structures are built with light wood studs and joists. The walls are typically constructed from 2 x 4 or 2 x 6 studs spaced 16" to 24" apart. These walls sit on top of the foundation and support upper floors and the roof. Plaster or gypsum wallboard is attached to the studs to form the interior finish. The exterior finish may be wood or metal siding, brick facing, or stucco plaster. New wood frame houses are required to resist earthquake forces, so some of the walls are usually constructed with sheets of plywood nailed to the studs behind the exterior finish.

The typical wood frame roof is constructed with 2 x 6 or 2 x 8 rafters spaced 16" to 24" apart. Roof sheathing (boards in older structures, plywood in newer buildings) is nailed to the top of the rafters, and the roofing material (shingles, shakes, tile, or built-up roofing) is applied to the top of the sheathing. The floors are usually constructed with 2 x 10 joists spaced approximately 16" apart. The floor sheathing, similar to roof sheathing, is nailed to the top of joists (see Figure 1 for an illustration of a typical wood frame building).

Sometimes a wood frame building may look like it is made from masonry or concrete. Most commonly mistaken is the stucco building. Stucco is portland cement plaster applied over wire mesh. Nearly all stucco houses are wood frame structures, although the stucco conceals the wood framing. Stucco is used as an exterior finish because of its durability; however, since stucco may not contribute to the strength of the house, stucco houses are not necessarily stronger than other wood frame structures. To determine whether there is a wood frame under the stucco, knock on the wall from the outside—the wall will sound hollow.

Another example of a disguised wood frame is the building with veneer. Exterior siding can look like metal or masonry; for example, there is an asphalt siding that looks like brick. To determine whether a building is wood frame, knock on the siding—it will sound hollow. Sometimes, wood frame buildings have a real masonry veneer which can "peel off" in earthquakes. If you have such veneer on your house, contact an architect or civil or structural engineer for a detailed investigation.

Building Age and Earthquake Safety

Earthquake safety in the design of wood frame houses has increased over the last 50 years, so the age of your building has much to do with how well it is designed to resist earthquakes. In general, the newer the building, the stronger it is likely to be in an earthquake. Building age can be determined from the following sources:

1) tax assessor's file
2) Sanborn map
3) building permit file
4) utility records

The local building department is a good place to start looking for your building's age because it will usually have a copy of the Sanborn map and other records. If none of those sources indicates the age of the building, the architectural style of the house can give an indication. Older buildings are sometimes renovated to look new, although this is not very common in houses. Knowing the age of your house will help engineers and architects decide what additional earthquake safety measures may be needed.

Foundations are often an area of weakness in older houses. Sometimes older houses do not have foundations at all, or they have weak ones. Most houses have perimeter wall foundations, which are continuous at the ground around the edge of the house. Many newer houses have concrete slab foundations that perform well in earthquakes. The most common problem in wood frame houses is in the area between the floor of the house and the top of the foundation—either this part of the structure is poorly braced or not well-bolted to the foundation. Over 23,000 homes were damaged in the Loma Prieta earthquake of October, 1989, and most of the damage was due either to lack of anchor bolting to foundations or inadequately braced cripple walls.

Even in recently constructed houses, there are features that have proven to be vulnerable to earthquake damage; most of them relate to the building configuration. Particular configurations have been associated with damage in past earthquakes:

1) house over garage (see section III.F.)
2) many large windows or doors (particularly at building corners)
3) large overhangs
4) split levels and complex geometry
5) stilts supporting the structure (as on a hillside site)

Unusual configurations are not necessarily hazardous, but if they are poorly designed or constructed, they can be particularly vulnerable to earthquake damage.

Collapse of a garage under the upper floor in the 1971 San Fernando earthquake.

Assessing the Existing Condition

You should gather some important information about your house before you start earthquake upgrading. Obtain original construction drawings or measure the dimensions of the existing building and structural members wherever possible. Also note whether there is access to a crawl space with sufficient room for the necessary work to be performed. This information will be handy when you talk to engineers, architects, and contractors.

When checking over your house, it is always advisable to look for rot or termite damage, especially when wood members are in close proximity to soil. The integrity of the structural members should be checked during any retrofit, and any decay in wood members should be considered in the design for increased earthquake safety. New and existing members should be protected from future deterioration with preservative treatments and decay-resisting construction methods. You will also want to note damage due to foundation settling and poor water drainage near the foundation.

Specific structural hazards, retrofit solutions, and costs are discussed in Section III. When there is doubt about a building's strength, it is advisable to contact an architect or engineer who is familiar with earthquake safety measures to review existing construction drawings and to evaluate the house.

An unreinforced masonry chimney that collapsed during the 1989 Loma Prieta earthquake. Note that bricks could easily have fallen through roof.

II. Earthquake Hazards

Geological Hazards

Geological hazards affect how a house performs in an earthquake. Many people think that the proximity of a house to an earthquake fault is the principal geological hazard, but strong ground shaking can occur miles from an earthquake epicenter or a fault line. Listed below are high-hazard areas:

- **Fault zone**—Quarter-mile-wide Special Study Zones have been designated around major earthquake faults. In a large quake, the ground in these zones may rupture. Structures in these zones may be seriously damaged, especially if they are built *on* a fault line. Maps of these Special Study Zone areas can be obtained from the California Division of Mines and Geology or from your local building department.

- **Geological hazard zones**—In these areas, a quake may cause intense ground shaking, settlement, landsliding, or liquefaction (earthquake-induced flow of water-saturated sandy soils). Unconsolidated, sandy soils, which underlie a large portion of the Bay Area's heavily developed areas, can shake much more strongly in an earthquake than firmer soils nearby. Many counties have geologists who may have specific data on stability of land parcels. A history of landslide, settlement, or major soil problems on a land parcel may be known to the county geologist.

You may want to consult with selected professionals about the potential for earthquake-induced landslides on or near your property. For instance, if your land parcel has been cut or filled, it is a good idea to hire a geotechnical engineer to evaluate the property. If your parcel is on a natural steep slope, confer with an engineering geologist about potential slope stability problems.

Maps showing hazardous areas are included in the ***Planning Scenarios*** for the ***San Andreas*** and ***Hayward Fault*** (Special Publications 61 and 78, respectively), which can be obtained from the California Division of Mines and Geology. The United States Geological Survey has similar maps.

- **Flood and inundation zones**—Areas that are subject to inundation from large storms or earthquake-ruptured dams and reservoirs have also been mapped. City or county planning departments, as well as local Offices of Emergency Services, have these maps.

Nonstructural Hazards

In an earthquake, injury and damage can result from the collapse of building elements that are not part of the wood frame structure. These elements are called nonstructural hazards and need to be properly braced to the structure, removed, or relocated. Common nonstructural hazards are:

- **Weak chimney**—Weak chimneys may collapse and the bricks fall onto the roof or the ground (see section III.G. for strengthening technique).

- **Tile roof**—Heavy roof tiles may shake loose and tumble down.

- **Unsecured water heater**—Water heaters can topple and cause fires and water damage (see Section III.H. for strengthening technique).

- **Trees**—Large, old, or leaning trees around your house may topple in an earthquake. Check for root rot or for large branches that are weak.

- **Large glass areas**—Large panes of glass can shatter into dangerous shards (see Section III. I. for strengthening technique).

- **Light fixtures**—Light fixtures inadequately tied to the building's framing can fall or cause damage as they swing.

- **Hanging plants**—Hanging plants can also fall or damage nearby windows as they swing.

- **Large, top-heavy furniture**—Tall bookcases, cabinets, or other heavy furniture can topple and cause injuries and damage.

III. Structural Problems and Strengthening Methods

Earthquake upgrading is done for two reasons: first, to guard against house collapse in an earthquake which could cause deaths or injuries; second, to reduce damage and economic losses. Major damage to buildings in earthquakes is usually caused by the failure of the weakest link in the structural system. Weak links can be upgraded to match the strength of the rest of the structural system, but it is not effective to strengthen one element of a structure to a higher level without strengthening others. You should also keep in mind that because it is more difficult to upgrade than to build new, it will probably be too costly to upgrade an existing building to the strength level of a new building. However, in most cases, you can significantly reduce earthquake hazards in your house.

The strengthening measures described in this section are ordered so that the most important and effective tasks are listed first. While this priority ranking may not be applicable to all cases, it is meant to be a guideline for making individual upgrade plans. The strengthening methods presented here are the most common ones, although there are other ways to achieve the same result. Housing design varies greatly in California so the most appropriate method will depend on each individual house and its setting. Heavier structures, such as multiple-story houses or those with tile roofs, may suffer more damage in an earthquake and should be strengthened accordingly. Strengthening work for unique buildings, such as those with unusual configurations or located on steep hillside sites, should be designed by an engineer or architect licensed in California.

Costs are provided to give a sense of the typical range. The average costs described are associated with construction done in ordinary situations. Strengthening costs will in fact vary from project to project. The costs quoted here are in 1990 dollars and are based on an average one-story Bay Area home approximately 2000 square feet in area on a flat lot. The costs include materials *and* labor and are what can be expected from a builder. However, if you intend to do the work yourself, you can save a large amount of money because materials account for a only a small portion of the total costs.

A. **No Foundation or Wood Foundation**—In some older buildings, there may be no foundation at all. During an earthquake, the entire structure can slide around on the topsoil and be heavily damaged. When there is no foundation, one must be constructed to connect the structure to the ground. The existing building must be temporarily supported by "shoring" while a new foundation is constructed. This involves hiring a house mover or contractor to lift and support the structure while the ground is trenched and forms for the perimeter foundation are built. Then the reinforced concrete foundation is poured and the existing structure is lowered and bolted onto the new foundation.

Typical Cost: $12/sf (square foot) for temporary support of one-story house

Typical Cost: $60/lf (linear foot) of foundation reconstruction

B. Unreinforced Masonry or Inadequately Reinforced Concrete Foundations—Older buildings may have brick foundations or concrete foundations that do not have enough steel reinforcement. These can collapse in an earthquake and may need to be completely or partially replaced. An architect, civil, or structural engineer can recommend the appropriate action to take. If the existing foundation is sufficiently strong on the whole, it may be strengthened at the points the new anchor bolts are to be installed.

When the entire foundation, or portions of it, need to be replaced, the house may need to be shored up as described above. The reconstruction work can be done with the building in place if the foundation is accessible from the outside or if there is a basement or tall crawl space through which a contractor can gain access. Portions of the building can be temporarily supported, the existing foundation excavated, and the new foundation constructed (see

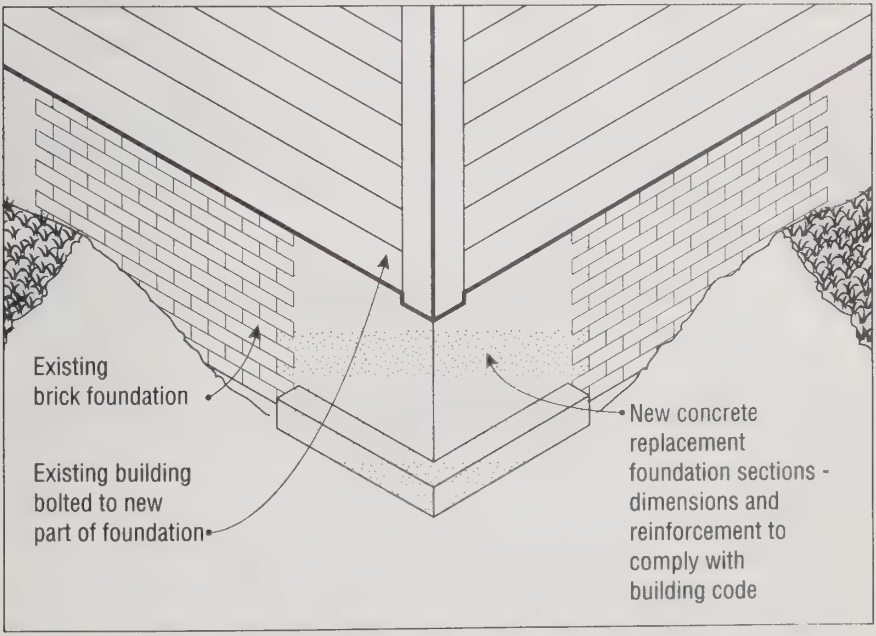


Figure 2: Retrofitting URM foundation by partial demolition and replacement.

C. **Pier and Stilt Foundations**—Many older houses are built on concrete piers or wooden stilts, without a continuous perimeter foundation. Because these footings are not connected to each other, they usually do not provide the strength the structure needs to resist shaking in an earthquake.

Pier foundations support houses on short columns attached to small concrete blocks. These structures need to be braced by a perimeter foundation and strong cripple walls. If access from the exterior allows, a new perimeter foundation can be constructed without shoring up the entire structure. The perimeter of the building can be lifted up slightly, the foundation built, and the house securely connected to the new foundation (see Figure 3). If access is limited, the house may need to be shored up for the foundation reconstruction.

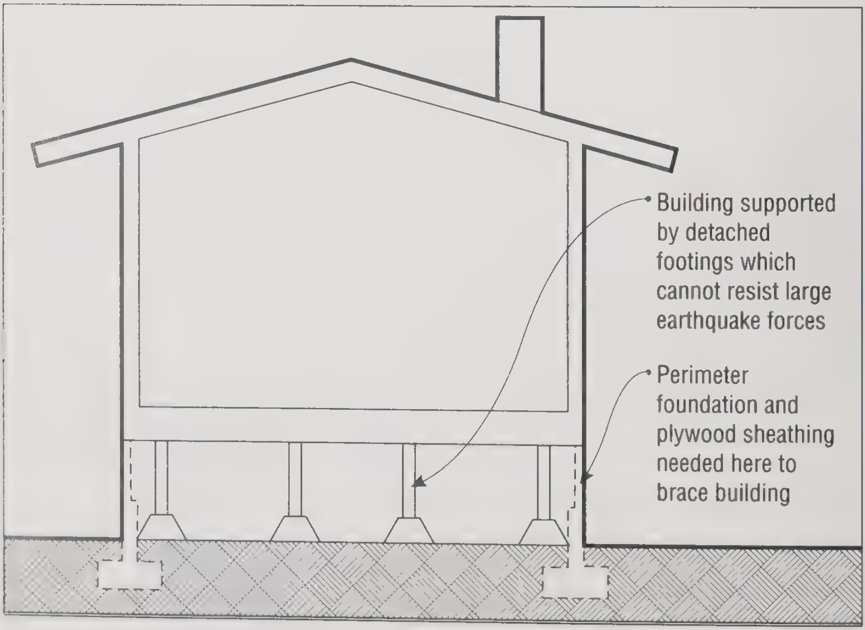


Figure 3: Houses with unbraced pier footings are vulnerable to earthquake forces.

Stilt supports generally are used in houses on steep hillsides, and involve tall 4 x 4's holding up the house on the downslope side. These stilts are generally very flexible, which makes the building vulnerable to earthquake damage. Stilts can be strengthened by adding diagonal braces or plywood walls between the stilts. Additional bracing should be added at the corners beneath the main structure.

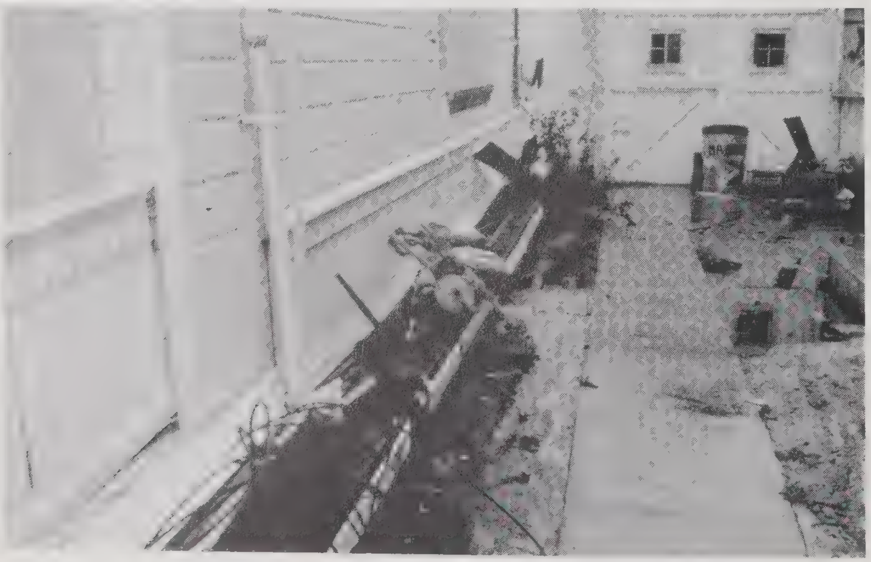
Houses with stilt foundations in Southern California.

D. No Foundation Bolts or Insufficient Ones—Many older houses are not anchor-bolted to their foundations or do not have *enough* bolts. Bolting was required in the 1949 ***Uniform Building Code***, but it was not uniformly enforced by local governments until 1958. In a damaging earthquake, the building can slide off its foundation. In new construction, anchor bolts are embedded in the concrete foundation so that the wall structure can be bolted to the foundation. To upgrade an older house, expansion-type or epoxy-type bolts must be placed in holes that are drilled into the foundation. The size and spacing of the new bolts depends on the weight and orientation of the house, and should meet local building code requirements.

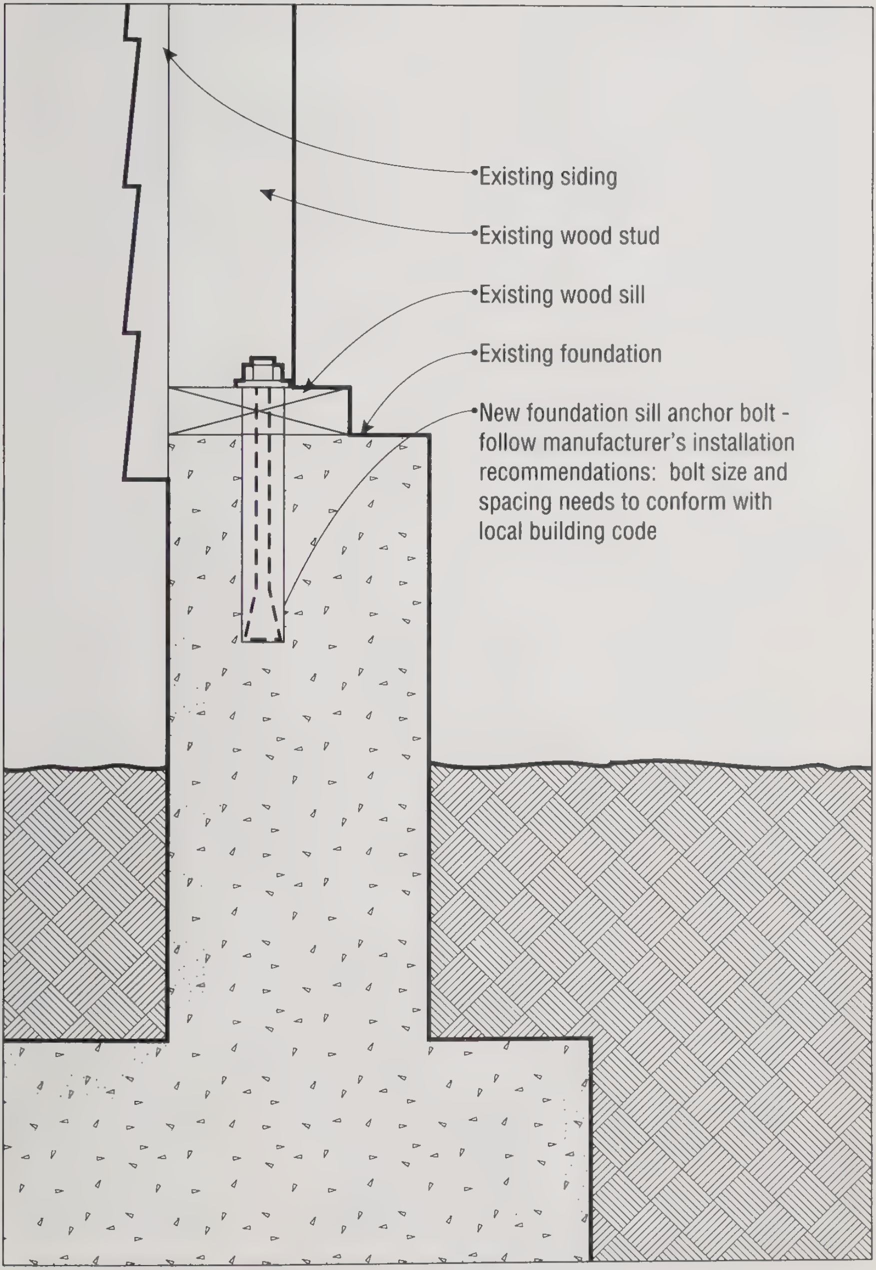
Usually, the most difficult aspect of installing foundation bolts is drilling in a tight space. When there is a cripple wall at least 18" tall, holes for the bolts can be drilled using a rotary hammer. Shorter crawl spaces require a right-angle drill; this usually takes a little more time (see Figure 4). The costs presented here apply to situations in which there are no existing bolts.

Typical Cost: $18/lf of foundation (right-angle drill)

Typical Cost: $12/lf of foundation (rotary hammer)

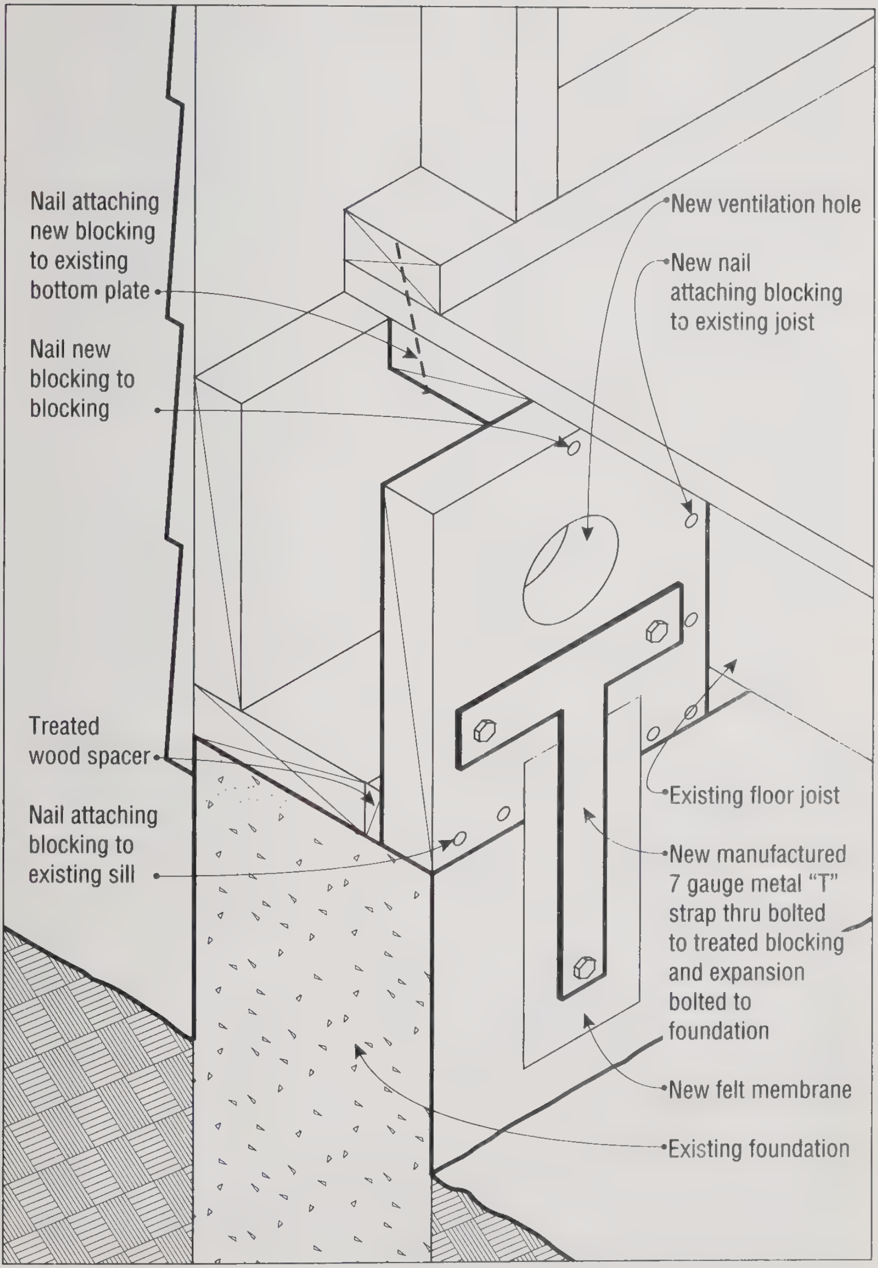


This house slid off its foundation due to insufficient bolting during the 1989 Loma Prieta earthquake. Note also the ruptured gas line.


Existing siding
Existing wood stud
Existing wood sill
Existing foundation
New foundation sill anchor bolt - follow manufacturer's installation recommendations: bolt size and spacing needs to conform with local building code

When the crawl space is minimal and the floor joist sits directly on the sill plate, the work is most difficult. In such a situation, holes cannot be drilled from above the sill. The house must be anchored to the sides of the foundation walls, provided that the existing walls are of adequate strength (you will need to consult with an engineer). Figure 5 shows a possible solution to this tight access problem.

Typical Cost: $23/lf of foundation


Nail attaching new blocking to existing bottom plate
Nail new blocking to blocking
Treated wood spacer
Nail attaching blocking to existing sill
New ventilation hole
New nail attaching blocking to existing joist
Existing floor joist
New manufactured 7 gauge metal "T" strap thru bolted to treated blocking and expansion bolted to foundation
New felt membrane
Existing foundation

E. **Weak Cripple Walls**—Houses often have short wood frame walls between the floor joists and the concrete foundation. Many of these cripple walls are not adequately braced, and this weakness allows buildings to shift sideways and collapse downward in earthquakes. The cripple wall can be strengthened by adding plywood panels. This reconstruction is usually done in the crawl space, so a low crawl space means greater difficulty (see Figure 6 for specific requirements). Strengthening can also be done from the outside, but this requires the removal of the exterior finish material.

Because the existing foundation sill is often wider than the stud, installation of plywood generally involves adding a new piece of blocking on top of and parallel to the sill, to provide backing for the plywood sheet. When the crawl space is two feet high or taller, the work can proceed easily.

Typical Cost: $15/lf for crawl space between 2' and 4' tall

When the crawl space is less than two feet high and the sill is wider than the studs, the difficulty is greatest.

Typical Cost: $20/lf

This house shifted sideways and collapsed downward in the 1989 Loma Prieta earthquake because of weak cripple walls.

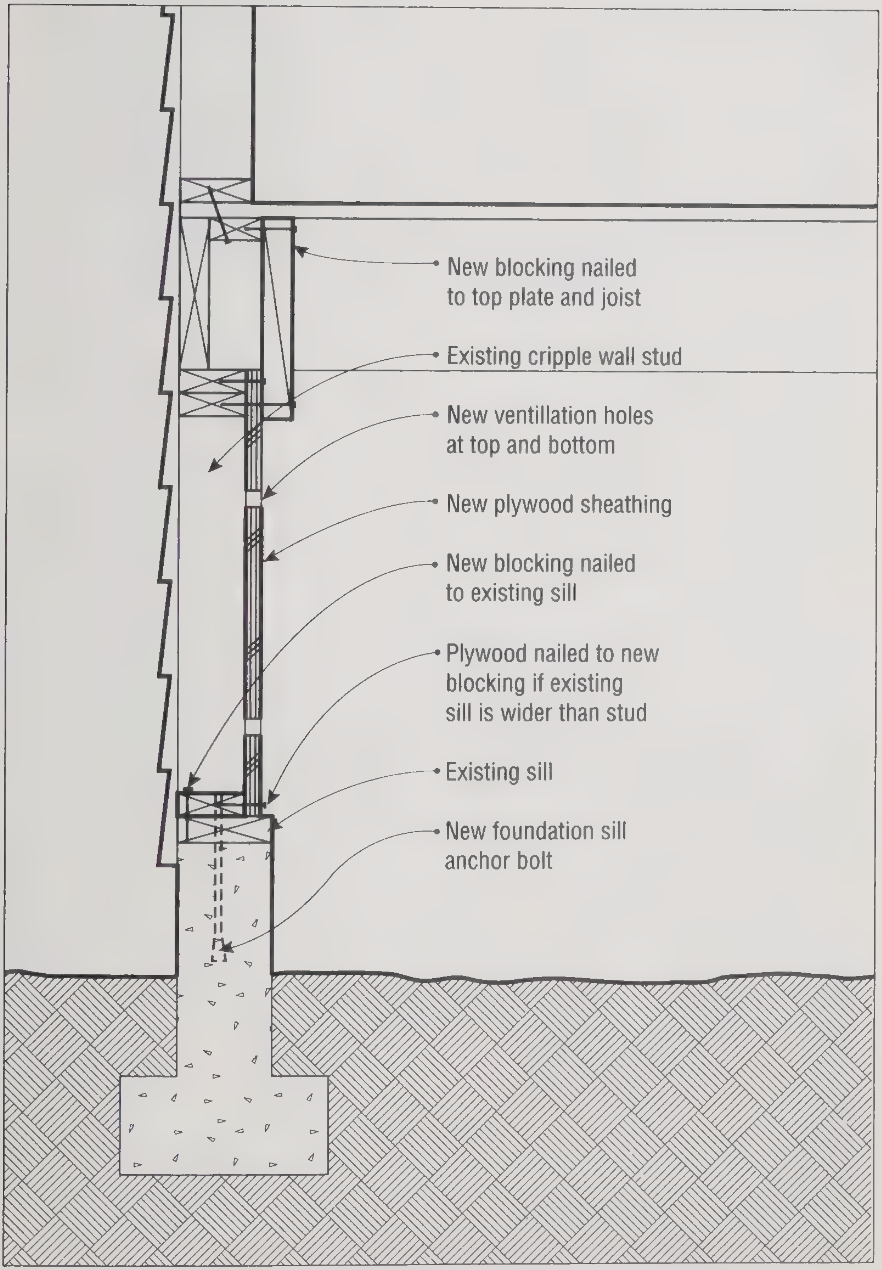


Figure 6: Strengthening cripple walls by adding plywood panels.

F. House Over Garage –Second stories built over garages are vulnerable to damage and collapse. Many garages have large door openings and therefore do not have the strength to brace the floor above against shaking in an earthquake. When there is 30" or more of wall space on both sides of the garage door opening, it may be possible to strengthen this configuration by attaching plywood panels to the wood stud walls on both sides of the opening (see Figure 7). This applies to an 8' ceiling, but the required width will vary according to the height of the wall and other factors. In order for the panels to be effective, their height must be less than 3.5 times their width. The new panels should be supported by blocking on all sides and should follow the requirements of the local building code.

Typical Cost: $24/lf of 8'-high wall panel

When there are no walls on the sides of the garage door, a steel frame can be added around the opening and tied to the wood structure, or a new wall can be constructed next to the garage to brace this portion of the building. This method will require engineering design.

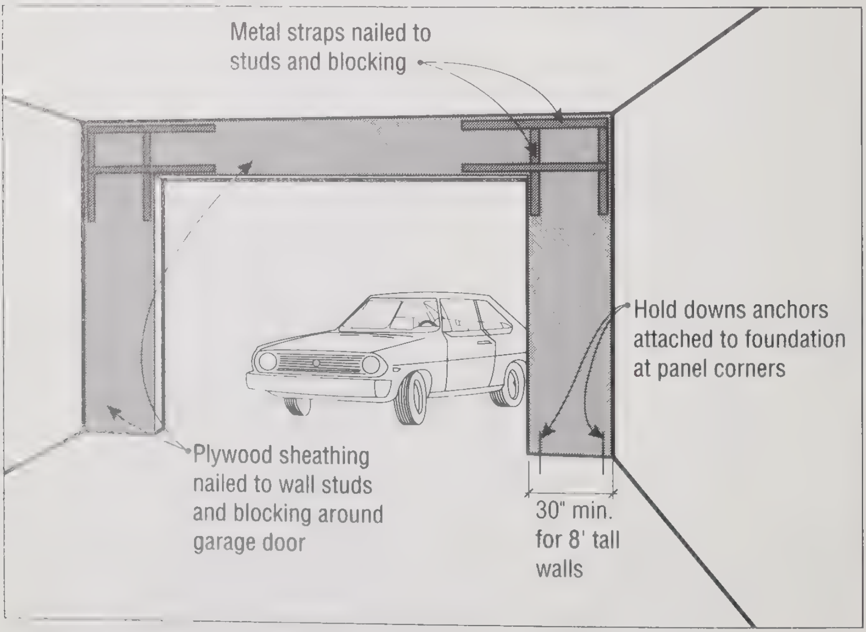


Figure 7: Bracing garage openings with plywood panels on each side.

G. Weak Chimney—Many older homes have unreinforced brick chimneys that extend several feet above the roof or stand against an exterior wall. These chimneys frequently collapse in an earthquake and can fall through roofs. If a chimney is unreinforced, the most effective alternative is to take it down and reconstruct it with proper reinforcement, or replace it with a lighter metal chimney. At the very least, the top of it should be taken down to a level of one foot above the roof and replaced with a metal flue approved for fire safety by a testing laboratory and the local building department (see Figure 8). The lower part of the chimney should be strapped to the structure; if the chimney is reinforced strongly enough, strapping should be sufficient.

Typical Cost: $325 for demolition of top portion and replacement with metal flue.

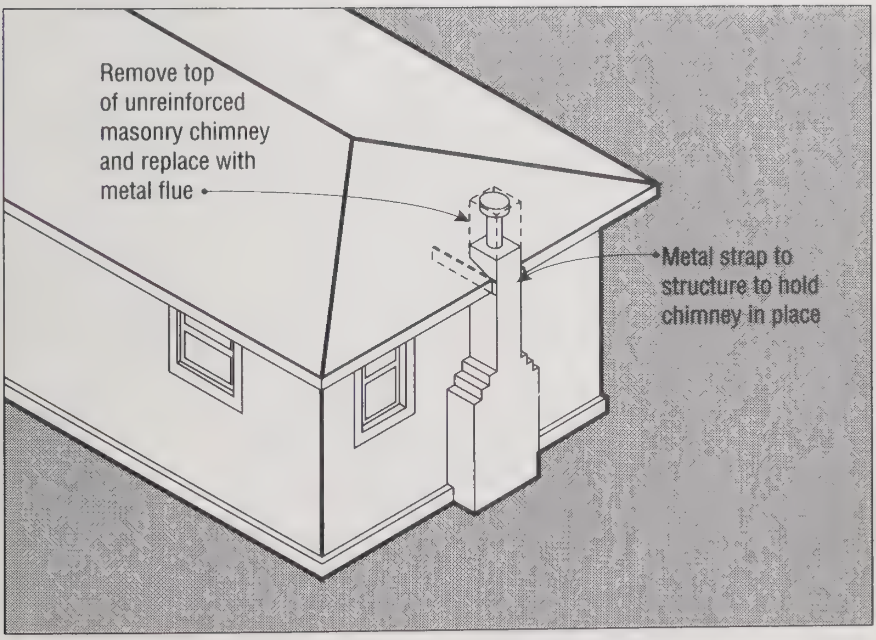


Figure 8: Reducing chimney hazards by removing the top.

H. Unsecured Water Heater---Water heaters should be braced to the wall studs to prevent overturning. When a water heater is located near a wall, it can be strapped to the studs by using electrical conduit tubing. The tubing is connected to the "plumber's tape" straps that encircle the water heater (see Figure 9).

Typical Cost: $75 per water heater

When a water heater is not near a wall, structural studs must be added around it. The new studs need to be attached to structural members above and below. Be sure to follow the local building code and maintain the required fire safety clearance between the water heater and the wood studs (usually about 6").

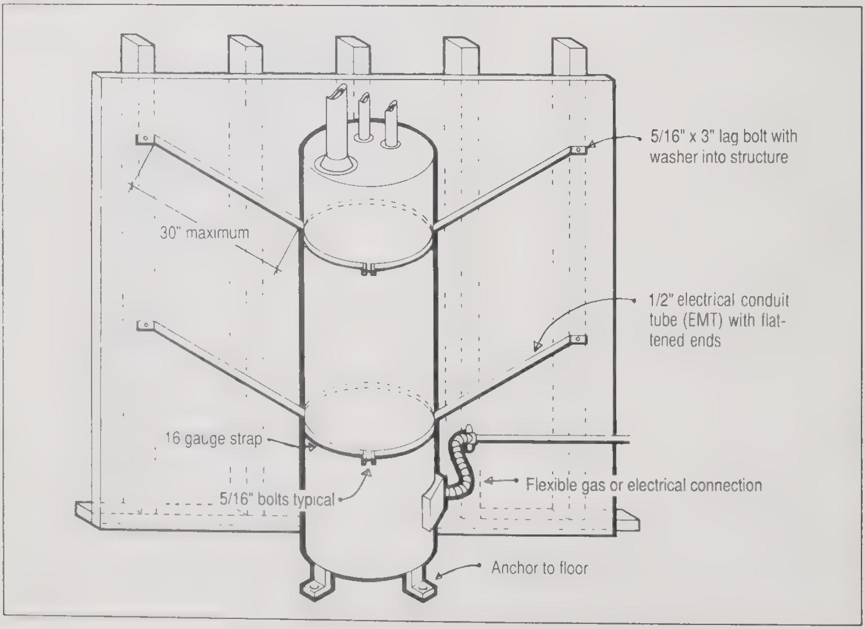


Figure 9: Securing water heaters.

I. **Vulnerable Windows**—Large windows, glass doors, and skylights need to be braced by solid wall or roof areas. Without adequate bracing, the movement of the house in an earthquake may shatter windows and skylights. Tempered or wired glass, or a layer of shatter-resistant film, can keep the glass from breaking into shards.

Typical Cost: $4/sf of film installed on glass

J. **Inadequate Shear Walls**—Shear walls are usually constructed using plywood panels nailed to wood studs. Many older homes do not have shear walls, but rely on let-in bracing or diagonal blocking. They are inadequate. In some instances, your engineer may recommend shear walls be added in the main portions of the house. If shear walls are to be added in areas where the wall finish is less important or where studs are exposed—for example, the garage, closets, and basement areas—the panels can be applied directly on studs.

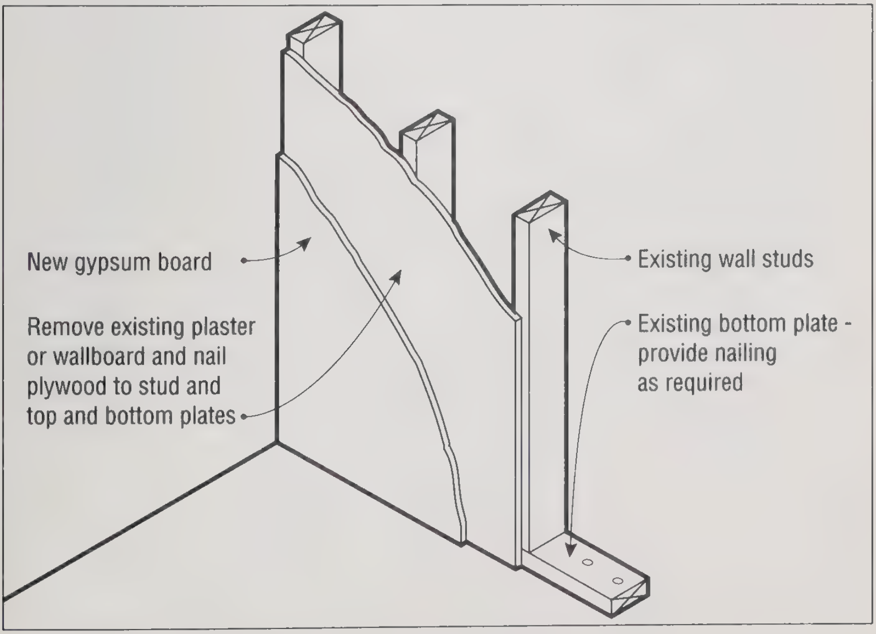


Figure 10: Typical installation of retrofit shear wall.

If shear walls need to be added in existing lath and plaster walls, the plaster and lath must be removed to expose the studs. A common approach is to use 3/8" plywood and 3/8" gypsum wallboard to bring a new finish level to the existing wall surface. In older houses where there is plaster decoration, the replacement of these specialty decorations will add expense (see Figure 10).

Typical Cost: $50/lf of 8'-high wall

K. **Porches, Balconies, and Exterior Stairs**—These exterior elements need to be securely attached to the main building structure. Earthquake safety upgrading usually includes installing metal straps or ties to make this connection. The difficulty of the work is related to the available access to the framing. When the structural members of the porches, balconies, or stairs are concealed by finish material and the finish surfaces must be removed, the work will be more difficult and more costly. When the structural members are exposed, anchors can be installed easily.

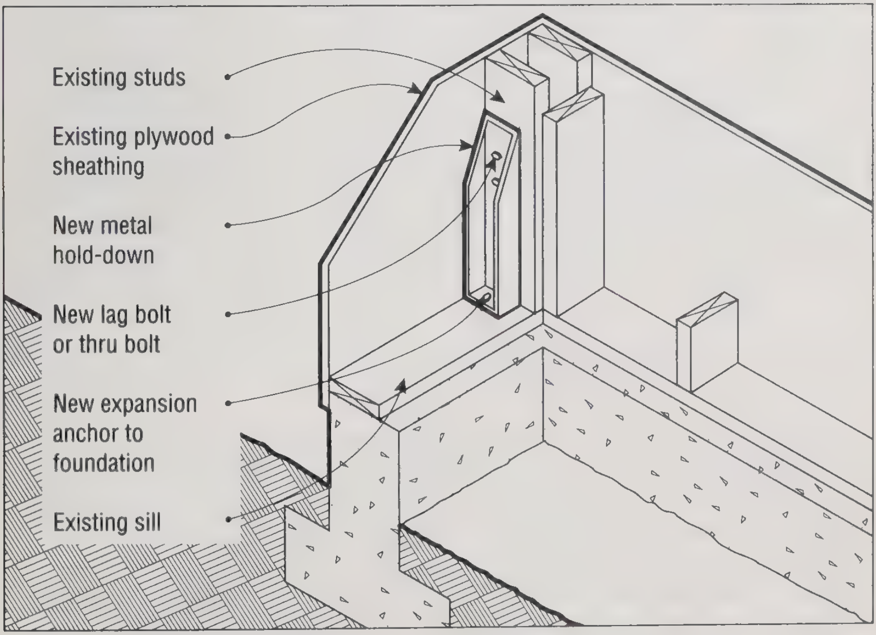
Typical Cost: varies

L. **No Foundation Hold-Down Bolts**—Hold-down ties are used to keep buildings or portions of them from turning over in an earthquake. Houses of average proportions do not tend to overturn or be lifted up, and hold-downs are usually not necessary. However, when the height of a house greatly exceeds its width, or when the house is on a steep slope, an engineer may recommend installing hold-downs (see Figure 11). Installation of hold-downs on the basement level is relatively simple since access is often possible in the crawl space. Only in rare circumstances will hold-downs be necessary on upper floors; installing them there will involve removing existing interior wall finishes and will cost more.

Typical Cost: $1000/house

M. No Column/Beam Connection Ties—In most walls, the column-to-beam connections are usually sufficient because of the nailing of floor members and other wall finish materials. These connections can be strengthened by adding sheet metal connectors. Strengthening these connections may require costly removal of finish material, but it is usually only necessary or appropriate for columns and beams in locations with no finish materials, for example, basements and garages.

Typical Cost: $25/connection



IV. Planning the Work

Doing Reconstruction Work

Earthquake upgrading will add value to your house, protect your investment, and help keep your family safe in the event of an earthquake. Though upgrading is itself a form of earthquake protection, having an upgraded structure will also allow you to obtain and maintain earthquake insurance. Insurance companies are required to offer earthquake insurance, but they are not required to continue coverage after the policy period. They are likely to cancel high-risk policies.

Construction in your home may inconvenience you and your family, especially if some of the upgrade work is performed in the main part of the house. In cases where the house has to be lifted up, you may have to relocate until the work is completed. Construction will also be noisy and messy; furthermore, the work may not be finished on time. It may also cost more than you expected because of unknown conditions uncovered during construction. Keep in mind that the work will provide valuable protection for you and your family in a future earthquake.

Earthquake upgrading can be done in conjunction with other improvements such as adding insulation, installing solar panels, termite work, or remodeling. Coordinated construction work will often lower total costs although it requires a larger initial investment. Another good time for strengthening work is when the house is empty, as when you are just moving in or are in between tenants in rental property.

Recommended Procedure

Earthquake upgrading work, including do-it-yourself projects, must follow all building code requirements in order to ensure the effectiveness of the strengthening. For all of the work, the current edition of your local building code should be used. For more complex projects, you should hire a civil or structural engineer or an architect to design the upgrade and provide plans and specifications for the work that needs to be done. The documentation will be necessary for obtaining a building permit and will serve as a detailed guide for the builder.

You or your contractor will need to obtain a building permit from your city or county building department before starting the construction work. The building department will charge you a fee for the permit. Securing a permit for construction makes the alterations legal and ensures compliance with local codes. Illegal alterations may jeopardize future resale of the house. Insurance companies may also use illegal work as an excuse to dismiss a claim in the event of a damaging disaster. Perhaps more importantly, obtaining a building permit will guarantee that building inspectors will inspect the work as it progresses and see that it is being done properly. Call your local building department to determine the length of time it usually takes them to issue a permit.

Last but not least, see that the upgrade work conforms to other codes such as plumbing, electrical, and fire. Don't make your home less safe in other respects while strengthening it for earthquakes.

Hiring Professionals

It is wise to hire an engineer or architect who is licensed in California and experienced with earthquake strengthening. Likewise, if you are planning on hiring a contractor to do the work, make sure he or she is licensed in California and has done upgrade work before.

It is advantageous to hire architects or engineers separately from contractors because the design professionals are knowledgeable about the structural problems, and will require only what is necessary. Engineers and architects can also help you get bids from different builders to perform the actual work, and assist you in any disagreement with the contractor. Remember that contractors are usually not trained to *design* structures or upgrades to them. The fee for an architect or engineer should be only a small percentage (usually between 10% and 15%) of the total work cost.

Selecting a contractor may be the most important decision you will make. The range of bids for the same design may vary a great deal, but the lowest bid may not be the best choice. The low bidder may not be competent, may use cheap material, or perform careless work. On the other hand, the highest bidder does not necessarily provide work of the highest quality. The best approach is to get bids from several contractors and/or get contractors who are recommended by other homeowners you know. Ask for references and an example of previous earthquake strengthening work; call previous customers to get their opinions of

the builder. Finally, select a contractor that you can communicate with because the ability to talk openly about the project will be extremely important to the success of the work.

It is not *required* that you hire a licensed builder; you may wish to hire workers to do the construction work and supervise it yourself, or do it all yourself. However, in the absence of a licensed builder, *you* must obtain the building permit and *you* will be responsible for both the work and the workers. Craftspersons may do good work, but make sure you carry worker's compensation insurance to cover them during the construction work. This kind of coverage is usually not included in a homeowner's policy.

Sources of Funds

Depending on the scope of the upgrading project, different types of financing strategies can be used.

In the simplest case, foundation bolting and cripple wall strengthening can be paid for directly because the cost is not typically prohibitive. If the project is more extensive, you may consider doing the work in phases, as money becomes available. Remember that the most critical work should be performed first. It is often more cost-efficient to perform several tasks at once because it reduces the contractor's overhead cost.

If the cost of the upgrading is substantial, several types of loans are available—home improvement (equity) loans, refinancing loans, life insurance loans, passbook loans, and personal loans. You should consult with representatives of your bank, savings and loan, or credit union.

V. Information Sources

Data on Land Parcels and Code Requirements

- Local Building and Planning Department
- Local Department of Public Works
- County Geologist

Geologic Maps and Studies

- Local (city or county) building, planning, or public works departments
- California Division of Mines and Geology
  660 Bercut Drive
  Sacramento, CA 95814
  (916) 445-5716
- United States Geological Survey
  Building 3, Room 504
  345 Middlefield Road
  Menlo Park, CA 94025
  (415) 883-8300

Earthquake Preparedness Information

- Bay Area Regional Earthquake Preparedness Project
  101 8th Street, Suite 152
  Oakland, CA 94607
  (415) 540-2713

- Southern California Earthquake Preparedness Project
  1110 E. Green Street, Suite 300
  Pasadena, CA 91106
  (818) 795-9055

- Local Office of Emergency Services

Other Assistance

Help in choosing a licensed contractor is available from:

- Associated General Contractors district office

- Council of Carpenters district office

Publications

Dwelling Construction Under the Uniform Building Code. 1988 Edition.
International Conference of Building Officials
5360 South Workman Mill Road
Whittier, CA 90601

Earthquake Planning Scenario for a Magnitude 7.5 Earthquake on the Hayward Fault. 1987. Special Publication #78
California Division of Mines and Geology
380 Civic Drive, Suite 100
Pleasant Hill, CA 94523-1997

Earthquake Planning Scenario for a Magnitude 8.3 Earthquake on the San Andreas Fault in the San Francisco Bay Area. 1982. Special Publication #61.
California Division of Mines and Geology
380 Civic Drive, Suite 100
Pleasant Hill, CA 94523-1997

The Home Builder's Guide for Earthquake Design. 1980.
Applied Technology Council
3 Twin Dolphin Drive, Suite 275
Redwood City, CA 94065

What You Should Know Before You Hire a Contractor. 1989.
Contractors State License Board
301 Junipero Serra Boulevard, Suite 206
San Francisco, CA 94127

VI. Glossary

Blocking: Short pieces of wood which are nailed perpendicular to, and in between, floor joists, studs, or rafters to stiffen these members and to provide backing for nailing of sheathing.

Cripple wall: A short stud wall, not a full story in height, extending from the top of the foundation to the bottom of the first floor. The purpose of the wall is to provide a level for the floor and to keep wood framing members away from the ground.

Foundation sill plate: A horizontal piece of wood that is bolted on the foundation and transfers the weight of the building to the foundation; usually of redwood or treated wood.

Shear wall: A wall which is designed to brace a house against side to side earthquake or wind forces. In wood frame houses, it is usually constructed by nailing plywood panels to wood studs according to an engineered pattern.

Sheathing: The structural "skin" of a building, made out of wooden panels or boards nailed to studs, joists, or rafters for supporting finish material or siding. When designed to do so, sheathing can act to keep the house rigid and standing in an earthquake.

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